Characterizing the Impact of Atmospheric Blocking on the Great Lakes' Regional Hydroclimate

Nicholas Dewhirst[1], Claire Pettersen[1], Jamie Ward[2]
[1]University of Michigan Department of Climate and Space Sciences and Engineering, [2]U.S. Army Corps of Engineers – Detroit District

Background

- Blocks are large, deep anticyclones that reroute prevailing winds meridionally.
- Quasi-stationarity of blocking facilitates persistent precipitation and temperature extremes (Lupo, 2021).
- Blocking is a major contributor to enhanced precipitation in high latitudes (Pettersen et al., 2022).

Motivation

- The Laurentian Great Lakes are the largest freshwater lake system on earth.
  - 20% of the earth's freshwater
  - Home to 30 million people
  - Over-lake precipitation, evaporation, and basin-wide runoff impact the lakes' water budget and levels.
- Little has been studied on the effects of blocking in the Great Lakes Region (GLR).

Science Questions

1. What is the frequency of blocking in the central and eastern United States?
2. How does blocking enable heavy precipitation in the GLR during the summer?

Frequency of Positive B

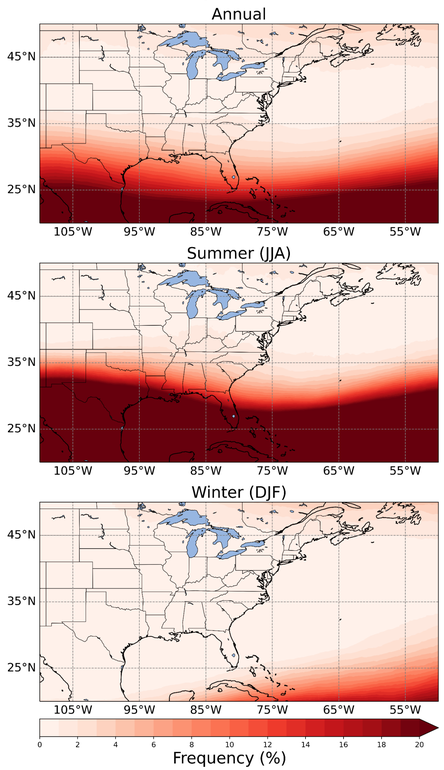


Figure 2: 45-year frequency of annual, summer, and winter positive B that satisfy the size requirement.

Blocking Detection Methodology

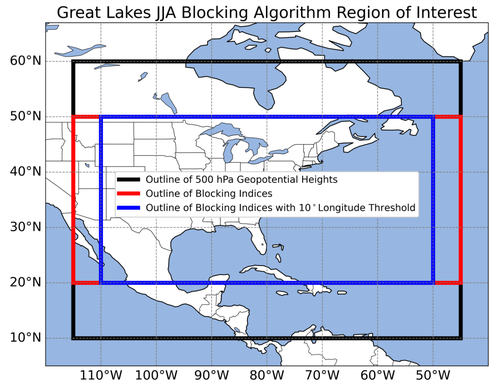


Figure 1: Visualization of the blocking detection steps beginning with 500 hPa heights (black), the blocking indices (red), and the filtered blocking indices (blue).

- Based on the algorithm by Masato et al. (2013)
  - ERA5 reanalysis 500 hPa heights from 1979-2023 at 18 UTC are used.
- **The blocking index (B)**
  - 500 hPa meridional height gradient
  - Positive values indicate a reversed gradient and easterly flow.
    - More positive → stronger anticyclone
    - Filter with a 10° consecutive longitude requirement.

500 hPa meridional height gradient → Blocking index: strength of anticyclone → Filter the indices with the size requirement.

Case Studies

August 18-24, 2023

- A block developed on August 18 and persisted through August 24, peaking in strength on August 21.
- Two long-lived MCSs developed within 24 hours of each other on August 23-24 over southern Michigan and Ohio, leading to flooding and severe wind damage.

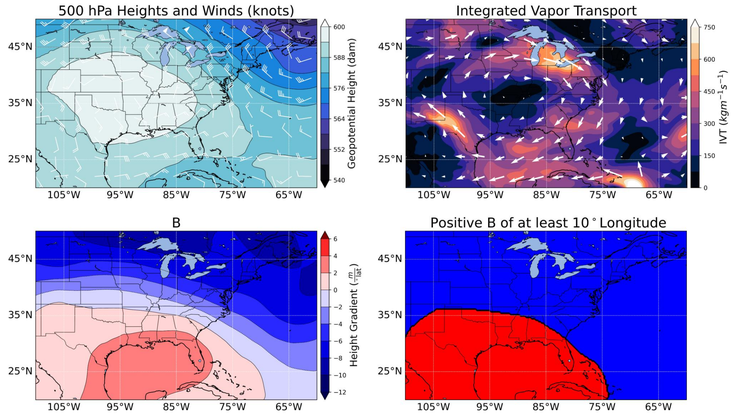


Figure 3: Synoptic setup at 18 UTC on August 23, 2023, preceding the MCSs over Michigan and Ohio. A strong anticyclone at 500 hPa with strong moisture transport in the lower Great Lakes is evident.

July 10-15, 1995

- A block developed and moved into the central U.S. by July 10, peaking in strength on July 13.
- Four derechos occurred across the northern U.S. from July 11-15, three of which directly impacted the GLR with heavy rainfall and destructive winds.

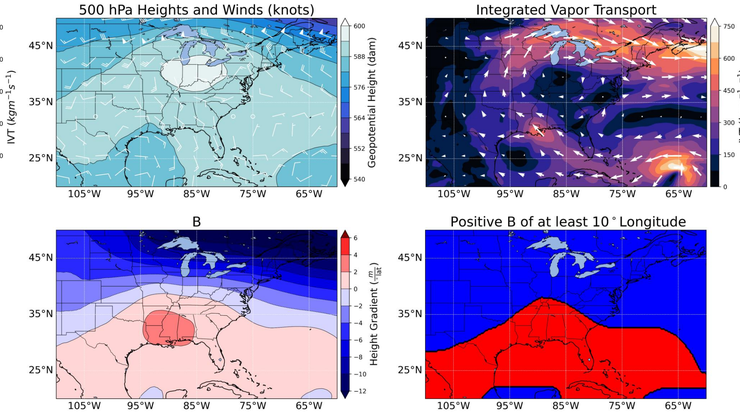


Figure 4: Synoptic setup at 18 UTC on July 14, 1995, prior to derecho development in the Upper Peninsula of Michigan. An anticyclone at 500 hPa with strong moisture transport in the upper Great Lakes is evident.

Blocking and Moisture Transport

- Searched for IVT > 500 $kgm^{-1}s^{-1}$ in the GLR and for positive B that satisfies the size requirement in the east-central U.S.
  - If the B are present on or up to two days prior, counted as an event → 866 events identified
    - All events averaged into a composite

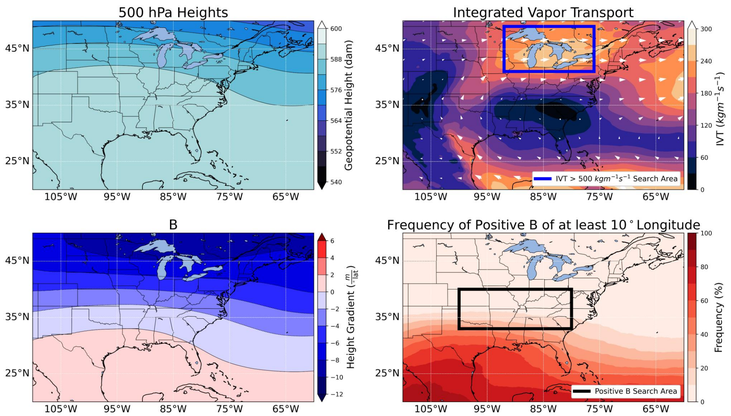


Figure 5: Composite plot of all events in JJA from 1979-2023 with IVT > 500 $kgm^{-1}s^{-1}$ between 41-49°N, 76-92°W and positive B satisfying the size requirement between 33-40°N, 80-100°W on the same day or up to two days prior.

Conclusions

- Summertime blocking transports moisture from the Gulf of Mexico into the GLR. IVT is enhanced in the GLR due to stronger flow.
- Blocking plays a role in supplying ample moisture to the GLR to facilitate heavy thunderstorm events.

Future Work

- Create a catalog of blocking episodes in the region of interest using time persistence and stationarity thresholds.
- Investigate how blocking influences winter precipitation and evaporation over the Great Lakes.

References

Lupo, A. R. (2021). Atmospheric blocking events: A review. *Annals of the New York Academy of Sciences*, 1504(1), 5 -24. https://doi.org/10.1111/nyas.14557

Masato, G., B. J. Hoskins, and T. Woollings, 2013: Winter and Summer Northern Hemisphere Blocking in CMIP5 Models. *J. Climate*, **26**, 7044–7059, https://doi.org/10.1175/JCLI-D-12-00466.1.

Pettersen, C., Henderson, S. A., Mattingly, K. S., Bennartz, R., & Breeden, M. L. (2022). The critical role of Euro-Atlantic blocking in promoting snowfall in central Greenland. *Journal of Geophysical Research: Atmospheres*, 127(6), e2021JD035776. https://doi.org/10.1029/2021JD035776

"THE MID-JULY 1995 DERECHOS: Series Overview." *Storm Prediction Center*, www.spc.noaa.gov/misc/AbtDerechos/casepages/jul1995derechopage.html.

Acknowledgements

This research is funded by grant number NA23OAR4310445 from the National Oceanic and Atmospheric Administration.